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OPERATIONAL SYSTEMS INTEGRATION METHODOLOGY FOR EFFECTIVE AND SUSTAINABLE MPC&A SYSTEMS IN THE FORMER SOVIET UNION

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ABSTRACT

Ensuring all aspects of the continued operation of installed Material Protection, Control, and Accounting (MPC&A) systems is a critical measure of the successful establishment of improved safeguards and security for nuclear materials at Russian sites. The installed systems must eventually be operable solely by the Russian sites, or the desired control over the nuclear materials will not be permanently realized. Effective introduction and implementation of new technologies and procedures for the enhanced protection of nuclear material at Russian sites requires a focus on the operational work processes supported at those sites. A number of US/Russian joint teams are following an upgrades methodology that seeks first to understand these processes and then integrate effective technologies that will result in a sustainable system. Process identification leads to effective procedures that in turn drive resource usage analysis and training programs. Performance tests of the system result in data that are used for appropriate system modification. Following this methodology allows for effective MPC&A systems that continuously improve and allow for a US role in the Russian site to evolve from implementation of upgrades to problem solution and assurance of the protection and accounting operations. In educating the sites to assess and understand their MPC&A procedures, the associated operational costs, and the methods to improve operations, the US is preparing eventually to phase out of this support role as the site's ability to assume that burden materializes. This paper will define and describe the sustainability concept, outline the methodology for ensuring MPC&A sustainability at upgraded sites, describe some success stories from implementation at pilot Russian sites, and offer suggestions for embedding sustainability and operational infrastructure in MPC&A systems as they are upgraded.

A. MATURITY OF THE SUSTAINABILITY CONCEPT

A basic principle of sound system design and implementation is the assurance that the system will operate continuously, and be self-sustained by the available resources. In the US/Russian MPC&A program this translates into ensuring that the right infrastructure is in place at Russian sites where MPC&A systems have been installed and making sure that the infrastructure is supplied, maintained, and continuously operated. At present, this support relies primarily upon US sources, but opportunities are sought by project teams in which the Russian share of the costs of increase until the operation of MPC&A system is self-sustaining under exclusively Russian resources.

US MPC&A site teams have continually been integrating sustainability concepts into their MPC&A system upgrades efforts. In addition, in recent years, the MPC&A program has established a team to work with the MPC&A staff at several completed Russian sites to establish the appropriate support infrastructure for the installed systems. This team has been designated the Civilian Research Reactor Sites (CRRS) team. The CRRS team has identified key tasks that contribute to the integration of sustainability into site operations.

B. SITE LEVEL SUPPORT AND NATIONAL INFRASTRUCTURE

The MPC&A system and its staff are both supported and driven from two directions. On the one hand the site itself must maintain the system, train its operators, and execute MPC&A operations to ensure adequate protection, control, and accounting of the SNM inventory. This site infrastructure has been the key focus of site upgrade teams and the program's sustainability team referred to above. On the other hand, Russian Federal authorities impose requirements on the sites for proper management and accounting for and protection of the nuclear material in their charge. This national authority promulgates requirements for operations and reporting and provides a national infrastructure to audit site operations, receive regular reports of Special Nuclear Material (SNM) movements and inventories, and impose penalties for improper or non-compliant performance. Figure 1 depicts the roles of the national and site infrastructures and indicates their primary elements.

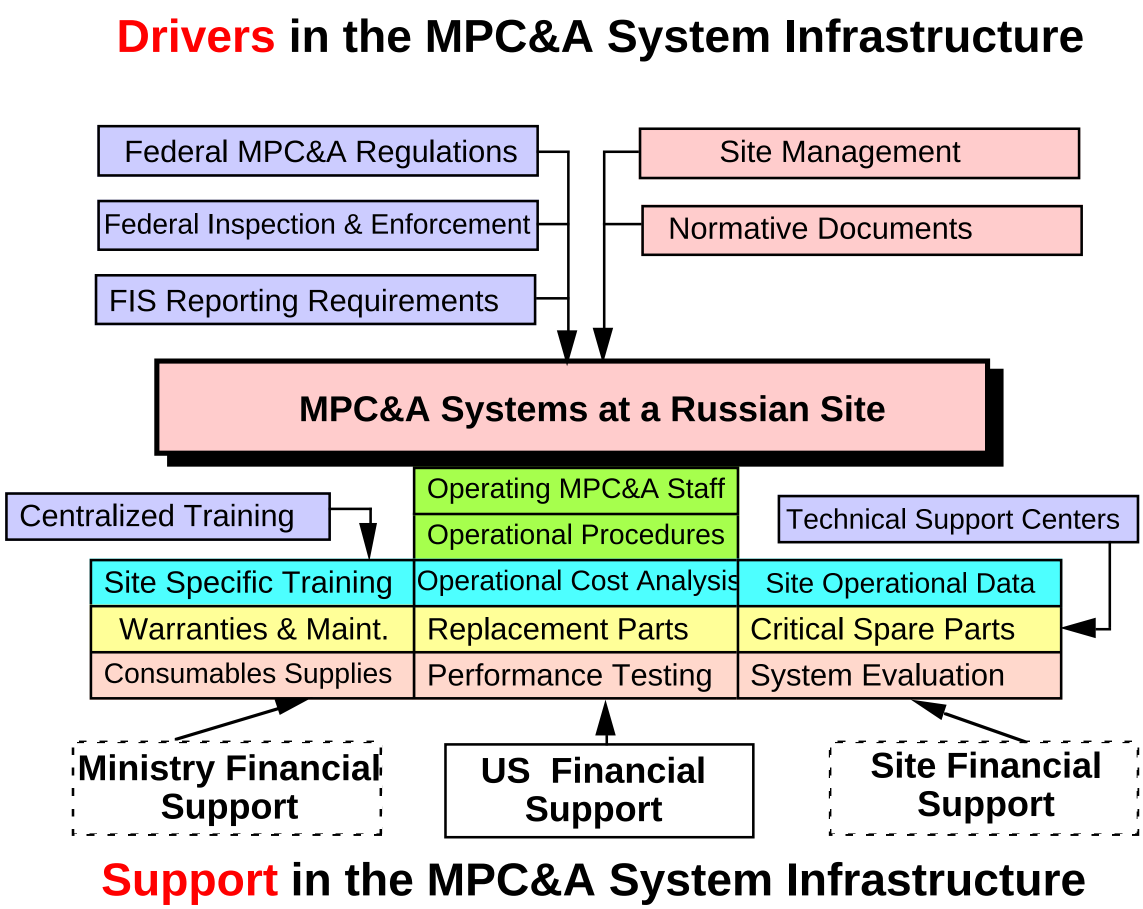

Figure 1. *The MPC&A system has a support infrastructure at the site and from the governing ministry. In addition, its operations are driven by federal requirements for management of its nuclear material. For genuine self-sustainability, US financial support needs to be absent, and all of the other support elements and operational drivers must be indigenous and active.*

The MPC&A system at a site is connected to elements that impose requirements on operations. These elements must be functioning in order for the MPC&A system to be self-sustaining. DOE supported

MPC&A is observing a trend where sites are beginning to be able to contribute more support to MPC&A operations, but additional work is required to fully transition all funding to Russian sources.

There are also Russian resources that fulfill a wholly supportive role. The two prime examples are the centralized training/education facilities that bolster the subject-matter expertise at the sites and regional technical support centers that can cover warranty, preventive and repair maintenance, and spare-parts needs for several sites in their vicinity.

C. MPC&A OPERATIONS ELEMENTS

1. Sound Engineering Approach to Technology Implementation

The installation or upgrade of technical MPC&A systems requires the application of sound engineering and systems principles. This ensures that the installed system will be self-sustaining and function as designed. The following elements of the system design, while certainly applied in the MPC&A upgrade process, also apply in the establishment of the appropriate support infrastructure. In developing these analyses for Russian sites, it is critical that the eventual site MPC&A staff perform the analysis, to ensure in-depth on-site knowledge and full ownership of the operations.

a) Process Analyses

The first step in the implementation methodology is to identify all of the critical MPC&A processes that must be carried out. Example critical processes are: inter-site and intra-site material transfers, alarm assessment and response, physical inventories, and emergency procedures. This analysis establishes the scope of the MPC&A activities and defines the basic operations and tasking for the MPC&A staff. While the vulnerability analysis process would have been used extensively in the original design of the MPC&A upgrades, it also comes into play as system sustainability is considered. Once the operating infrastructure is identified, it should be evaluated in the context of how well it covers vulnerabilities associated with interruption or cessation of any operations because of resource limitations.

b) Human Resource Analyses

Once the system scope and functional specifications are identified, then the personnel requirements can be identified that are needed to carry out the operations. It is necessary in this step to define not only the number of personnel but to also the specific tasks that each category of MPC&A staff must perform. This job-task analysis will lead easily to clear assignment of duties and responsibilities and to the identification of the training each MPC&A worker will require.

c) Procedure Development

The detailed definitions of critical MPC&A processes and the associated tasking leads naturally to documented procedures for carrying out the operations. Documenting the procedures is most effective if each process is thought through by applying all possible scenarios, including anomalous situations and emergencies. Process flow charts have been found by the CRRS team to be particularly effective in communicating the flow of work and decisions in these critical processes. Tabletop discussions, considering all possible procedural decisions (including emergencies and anomalies), are an effective way to develop reliable procedures. Established procedures reduce variability in operations and define clearly the subject matter for operational training.

d) Site-Specific Training

Once procedures are fully defined, then a training program must be employed that educates all authorized personnel in the taskings and responsibilities they will have in the operation of MPC&A systems that are site-specific. To be sustainable, operations training should be developed, presented, and evaluated by indigenous resources. The training staff must first identify the tasking that each type of person will be expected to carry out and then assign training accordingly. The training staff may need to bolster their own expertise through training courses available from centralized training and educational facilities (such as RMTC, ISTC, and MEPhI) in the National infrastructure (see section 3a below). Then that staff will develop and present the on-site training program for the MPC&A workers.

e) System Evaluation and Performance Testing

An essential part of system maintenance and continuous quality improvement is the periodic testing of the system components and operations as a whole. Component testing may also involve equipment vendors and site maintenance staff in a preventive maintenance role. Testing of operational procedures also exercises system components, but, more importantly, it tests the integrated operation of the whole system. Equipment interactions are tested, and staff proficiency is evaluated. Performance tests therefore offer a unique opportunity to evaluate the effectiveness of the site-specific training program and to recognize where training might need to be improved. Concomitantly, system evaluations/performance testing contribute to routine equipment calibration, and identifies opportunities to establish preventive maintenance plans and evaluate lifecycle replacement of components.

f) Cost Analysis/Operational Cost Model

An essential element in understanding the necessary scope of the MPC&A system support infrastructure is a detailed analysis of the site's MPC&A system operational cost. This information is invaluable in establishing the US obligation for out-year support as Russian ownership is phased in. The information also alerts the site management to the expected costs associated with operating and maintaining their system. The operational cost model developed from such analysis will accommodate routine operations (including labor for MPC&A operators and guards), equipment replacements, spare parts and consumables, on-going training and system evaluation, and anticipated system upgrades or updates. Results from these studies at the CRRS sites are summarized below.

2. Site Level Infrastructure

The site-level MPC&A infrastructure is closest to routine facility operations and thus, has the most immediate and lasting effect on the quality and endurance of the MPC&A work at the site. The elements of this infrastructure described here constitute the primary focus of the MPC&A Program's CRRS Team at the high-priority commissioned CRRS sites.

a) Configuration Control

As mentioned earlier, the first step to establishing a coherent system requires documentation of the critical processes that the system performs. In MPC&A, this translates into defined procedures and taskings that accomplish these critical tasks. Once this configuration of operations is established, any significant changes in that configuration must be analyzed for impact on the mission of the system before being implemented. In this way, the viability of the operating system and its compliance with operating and reporting requirements are maintained, and the impact of changes on the operations are understood and accommodated.

b) Site Training Capability

The central MPC&A training facilities have an important mission to maintain indigenous MPC&A expertise (train the trainers) throughout the Russian nuclear complex. However, to execute MPC&A operations at each site, it is necessary to establish a site-level MPC&A training program. Such a program combines Russian Federal requirements, sound operational and scientific practices, and the unique features of the site into a program to train the MPC&A staff to carry out their taskings. Training program instructors must be subject-matter experts and effective communicators in order to convey the required materials to the workers at large. Training is an on-going need in all areas of a site's operations. As such, provision must be made to train new employees and to re-train experienced employees to ensure that current knowledge is maintained and that mentoring or on-the-job training is taking place. (See Refs 1 and 2).

c) Equipment Maintenance, Testing, Repair, Calibration

The performance of system components should be monitored on a regular basis to ensure equipment is operating properly and to assess any upgrade or replacement needs that may head off unanticipated failures that can disable the system. A regular program of performance testing serves this need and also evaluates the quality of the operations and the training of personnel. Site should develop a regular performance-testing plan that includes component testing, preventive maintenance, and system-wide exercises to assess procedures, system functionality, and training.

d) Nuclear Material Measurements and Reporting

Some of the MPC&A system equipment items are the measurement instruments that determine and track the quantities of nuclear material in containers, equipment, shipments, receipts, and locations. The choice of instruments and measurement techniques are driven by material types, desired (and/or required) accuracies and precisions, throughput, and other measurement-capacity considerations. The ultimate product of a sound SNM measurement program is a fully measured material balance and in-depth knowledge of the statistical significance of the inventory difference. The measurement and inventory results need to be conveyed to the site's centralized inventory records, which are eventually combined into a material balance and associated reports to the FIS. The measurement equipment must be certified (national infrastructure), calibrated (national and site infrastructure), maintained, and kept up to date and in calibration.

e) Protective Force

The Protective Force are the MPC&A staff associated with the response duties at the site. They may include both site and external personnel. The Protective Force component must be trained, supplied, and evaluated, and their equipment must be maintained and kept up to date. Both the site and the employer of the protective force itself may share the responsibility. Assurance of a reliable infrastructure, with all of the proper elements outlined here, is a challenge in coordination between the site and the provider of the protective force personnel.

f) Emergency Management

The overall question of emergency management affects MPC&A systems since emergencies can disable the system or its resources or compromise established procedures. In many emergencies, life safety considerations dictate personnel movements and nuclear material management procedures that would not be approved under normal operations. MPC&A procedures have to be developed with these emergency possibilities in mind, so that the MPC&A systems can recover after the emergency with maximum knowledge of the status of the nuclear materials and access controls during and after the event. The process of procedure development discussed above in section 1.c should include such provisions.

g) MPC&A Systems Management and Administration

The oversight of the MPC&A activities at Russian sites is typically handled by a Chief of Security and a Chief Safeguards officer. These managers have staff that perform the various functions mandated by the MPC&A procedures. These personnel require expertise on the Federal MPC&A regulations, the facility policies and normative documents, so that they can manage procedures correctly. The administration of MPC&A should have the ability to keep accurate and compliant records and to generate appropriate reports to facility management and the federal authorities. Finally, the MC&A and PP staff should, to some degree, be organizationally independent of the site management, so that oversight of operations and compliance is as free from inappropriate management influence as possible. Senior site management should empower the MC&A and PP staff to enforce compliance with federal and site MPC&A regulations and policies to include personnel reliability programs.

3. National Level Infrastructure

Most of the elements of the national-level infrastructure make demands on the site MPC&A system in operational quality and reporting. Ultimately, however, some if not all of the financial support for maintaining required MPC&A operations will also have to come from the mandating body, such as the governing ministry. In addition, there are other national resources already being applied to support site MPC&A operations. This section outlines these federal-level elements of the infrastructure.

a) Technical and Methodological Support

The need for some degree of standardization in MPC&A operations, methods, reporting, and technical content dictates that the associated expertise and knowledge of regulations and accepted procedures come from a common source. The Russian central MPC&A training and educational facilities (Ref 1) fulfill this role very well by providing extensive MPC&A training curriculum to create consistent subject-matter expertise in all areas of MPC&A. Sites should integrate their use of these resources into their preparations for and development of the site-specific training program.

b) Equipment Support

The equipment used in MPC&A operations needs on-going maintenance, repair, and eventual replacement. The site personnel who are typically trained by equipment vendors, can handle some of this type of work on site. However, centralization of some of these equipment services allows sites to focus more on their nuclear and MPC&A missions and rely on others to keep the equipment running and up to date. Regional equipment support centers are being considered to service some of this need (Ref 3).

c) Reference/Calibration Materials Development

The measurements made in support of materials accounting are essential to the establishment of a fully measured material balance. These measurements (procedures and equipment) must be certified in order for their results to be legally usable in the Russian national accounting system. Part of the certification of the quality of the measurements is the certification of the standards used to calibrate the measurement instruments. In the case of destructive and nondestructive assay of the nuclear materials, these standards must be produced by methods that establish their mass and isotopic values in a manner that is traceable to the national (and even international) system of weights and measures. Russian resources are being developed to support the technical development of certifiable standards for all stages of measurement calibration and standards production. (Ref 4).

d) Adherence to National Nuclear Material Accounting Reporting Requirements i.e., the Federal Information System (FIS).

Since the site SNM inventories are a part of the national holdings of SNM, each site will have to report the status of its inventory to the central national authority (FIS) on a periodic basis. This federal information system will impose reporting requirements on the sites that will dictate certain capabilities in the inventory process and in the record-keeping resources. The reporting requirements are one of the key drivers in motivating the full operation of the MPC&A systems.

e) Inspection Support

Federal MPC&A regulations are still under development, but it is clear that levels of accounting and security on nuclear materials will be defined by the sensitivity and size of the site's SNM inventory. Inspections by the governing ministries and Gosatomnadzor (GAN) will monitor compliance with these regulations. Inspections are another form of system performance testing, with statistical verification and general oversight included as well. As such, inspections can be a form of support for the MPC&A system, in that they offer critical feedback for system improvement. However, inspections are effective only if they are accompanied by strong enforcement provisions that impose significant penalties for non-compliance.

f) Certification and Attestation Requirements

Any technical system, especially one that manages critical (and hazardous) assets like nuclear materials, must be operated with approved procedures and equipment and by certifiably trained personnel. The Russian system takes this requirement further by requiring formal certification of essentially all aspects of MPC&A operations. While this formal certification process is not one that the US program supports financially, it is a necessary means by which the quality and effectiveness of the system can be enforced.

g) Transportation

In addition to MPC&A needs for intra-site transportation of nuclear materials, the inter-site shipments also require support to maintain an acceptable level of accounting and security on the materials in transit. This vulnerability is covered by the federal resources: security is provided by federal personnel, and the materials accounting is relegated to the FIS during transit. Development of this national MPC&A resource is described in Ref 5.

D. EXPERIENCE AND SUCCESSES OF MPC&A OPERATIONS ELEMENTS AT RUSSIAN SITES

1. Operational Cost Analysis

The Civilian Research Reactor Sites (CRRS) Team has tasked four of the high-priority commissioned sites (MEPhI, JINR/Dubna, Khlopin, and Krylov) to analyze their anticipated costs for full operation of their installed MPC&A systems. These sites are largely item facilities, with significantly smaller inventories than the larger fuel-fabrication and reprocessing sites. These analyses have been completed, and the results are summarized in Table 1 below (See also Ref 6).

The information is broken out by gross category, and three levels of cost are considered. The "initial costs" involve stock-up and start-up costs associated with getting spare parts inventories established, procedures de-bugged, and people trained. The "steady-state" costs are those that are supported by the US program. The "RF costs" are those to which the steady-state operations settle, once the systems are operated and maintained solely through Russian resources. The RF costs are lower than the steady-state (US) costs because of the lower pay scales for Russian labor paid by the sites, compared with the rates used in US contracts to Russian sites.

Table 1. Average annual costs required to sustain operation of MPC&A Upgrades at small Russian nuclear facilities.

	Spare parts/tools	Vendor support	Consum-ables & replace-ment parts	Warranties	Perfor-mance test program	Training program	Immediate needs (covers obvious vulnerabilities immediately)	RF Labor	Total
Initial Costs	$23,314	$11,667	$6,600	$15,000	$32,667	$31,333	$19,667	Rolled up in other costs	**$154,000**
Steady-state costs	$13,400	$10,000	$3,167	$15,000	$27,333	$27,000	$14,000	Rolled up in other costs	**$120,000**
RF Costs	$13,400	$10,000	$3,167	$15,000	$27,333	Included in RF Labor	Included in RF Labor	$8297	**$91,000**

2. Availability of Templates for Sustainability Contracts.

The CRRS Team has developed statements of work (SOW) for implementation of the various elements of the site-level sustainability infrastructure. These documents are templates of contracts that have been issued to the commissioned sites addressed by the CRRS team in its pilot sustainability effort. To date, they have been shared with eight site teams, and they are currently available to all active site teams to use to integrate sustainability measures in their upgrades processes. All of the site upgrades teams are integrating sustainability concepts into their upgrade plans. The availability of these sample SOW helps formalize the process through site contracts and focuses the sites' attentions on their eventual obligations for full stewardship of their MPC&A systems.

E. PLANNING HORIZON

The goal of sustainability efforts is to find the method by which the US can establish commitment from site managers and federal structures and leave that site with a properly operating MPC&A system that they can sustain on their own and with their governing ministry's resources. The main elements of the sustainability strategy at the site level are:

- Establish a complete operational and support infrastructure necessary to sustain proper MPC&A operations at the site (including educating the site on all aspects of operation and support).
- Aggressively implement cost sharing for operation and support wherever possible, and progressively increase the site's share of the operating costs at every opportunity.
- Identify triggers that signal the ability of the site to assume full responsibility for the systems (e.g. assuming responsibility for all maintenance and repair).

The life cycle of US effort at a site, from initial negotiations through the upgrades, then sustainability, then transition to site stewardship, is depicted in Figure 2. Reaching an exit point in the US support of sustainability at a site needs to be a transitional process, rather than a sudden change in operating arrangement (See Figure 2). Project teams should develop site-specific transitions to identify a methodology for the sites, where possible, to gradually increase Russian responsibility for sustaining and operating their systems as early in the upgrade process as possible. High-cost items (e.g., spare parts, replacement and update of system components, *etc.*) would likely be the last elements that could be assumed by the site. However, initial steps might involve only assumption of responsibility, reporting, assessment, etc. These activities would help the site MPC&A personnel to exercise their stewardship of the system in affordable ways and help accelerate the required culture shift to conscientious MPC&A operation. Then the cost-sharing can move toward more costly items such as spare parts, warranties, training, etc., as opportunities present themselves.

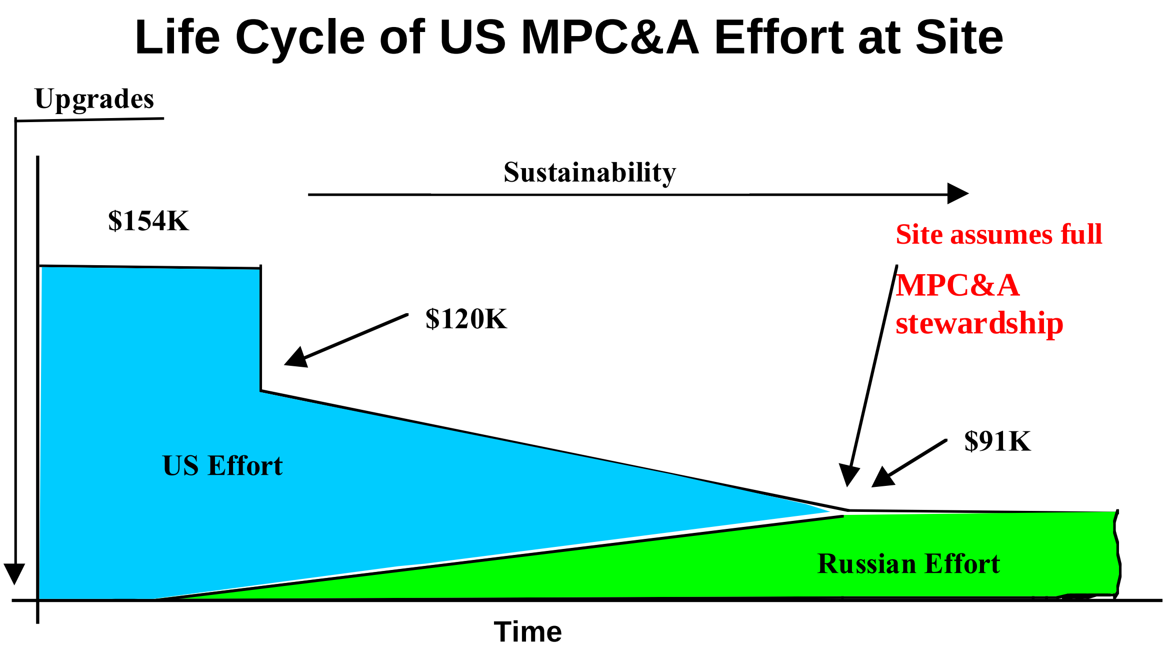

Figure 2. *Schematic of US level of effort through the life cycle of an upgrades project. Site-focused sustainability stages of the work are shaded. Emphasis is given to the ramping up of sustainability measures during the upgrade process, to assure that the operating MPC&A systems are properly equipped and supported from the beginning(blue shading). Once upgrades are completed, there may be an additional infrastructure-building phase that involves stocking up on spare parts, development and initial presentation of training, and establishing maintenance, repair, and testing programs. Once the site sustainability infrastructure is established, then sustainability costs decrease to steady-state maintenance, repair, testing and evaluation of the system, and training of personnel. Then, at some appropriate point, the Russian share of the sustainability costs is increased, and the US share is phased out until the MPC&A system and operations are self-sustaining.*

Under a plan such as suggested above, when the US program begins to look for specific exit opportunities, the sites will be better prepared for and practiced at running their own system. Furthermore, if they have been actively engaged in identifying all of their operational costs along the way, they (and their eventual funding sponsors) will be better prepared to specify the costs that need to be supported from site and federal resources.

F. CONCLUSIONS

The US MPC&A program is addressing sustainability of system operations on two fronts: the upgrade process installs sustainability measures as systems are designed and implemented, and the site is continually prepared for eventual ownership of the MPC&A system. Once the site enters the operational phase, program-wide projects are developing resources and methods to assure the presence of the right site and national infrastructures that both support and motivate proper operations. The transition of operations from US support to wholly Russian stewardship is developed in the context of

- Education and training of site and federal personnel
- Cost-sharing between US and Russian resources with as much growth in the Russian share as possible
- Identification of criteria that signal Russian federal and site-level readiness to assume full control and support of their MPC&A systems.

The US investment in MPC&A upgrades at Russian sites has resulted in spectacular improvements in the quality and effectiveness of MPC&A operations and a commensurate reduction of the risk of undetected theft or diversion of NM from site control. Careful and aggressive implementation of sustainability measures and support of the operational infrastructure at these sites protects this investment by assuring continuous operation of these systems. In addition, the program recognizes the need to implement cost-sharing measures to work towards eventual full transfer of ownership and control of the systems to Russian personnel.

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